An analysis of human damage caused by recent heavy rainfall disasters in Japan

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Abstract: The development and analysis of a database that will aid in the mitigation of human damage (that is, deaths or missing persons) caused by natural disasters are very important, and a method to do these tasks has been established in Japan. First, we developed a victim database for the typhoon No. 0423 disaster, the typhoon No. 0514 disaster and the heavy rainfall disaster of July 2006, and the victims were classified based on whether they were dead or missing. In the present study, we estimate whether any loss was mitigated by the use of disaster information. In the case of the typhoon No.0514 disaster, the estimated mitigation percentage of victims is 75%. However, in the case of the typhoon No.0423 disaster, the mitigation is only 36%. Disaster information is a useful disaster mitigation measure, but there is a limit to its effect.

Key words: *heavy rainfall disaster, deaths or missing persons, disaster information, disaster mitigation.*

1 INTRODUCTION

Analyzing the causes of death in a natural disaster is important for disaster prevention efforts. In Japan, there have been studies on the causes of death during earthquakes (Japan's National Land Agency, 2000, Kobayashi, 1981), and there have been several studies on the human damage caused by heavy rainfall disasters, such as the case studies of the "Nagasaki heavy rainfall" (Matsui et al., 1984, and others). However, since the mid-1980s, little attention has been paid to the causes of death by heavy rainfall disasters, probably because no such events have occurred since the Nagasaki event in which many people were killed. What is important in the mitigation of human damage by heavy rainfall disasters is advances in non-structural measures, especially in the gathering and dissemination of disaster information, such as warnings, hazard maps, communication systems and the like. In Japan, disaster information has changed considerably in recent years, so persons involved in disaster prevention must analyze human damage under present-day conditions.

The purposes of this study were:

1) Construction of a death or missing person database based on the data of recent heavy rainfall disasters; and

2) Estimation of the number of victims whose death or missing status could have been mitigated by the use of disaster information.

In this paper we are concerned with three recent heavy rainfall disasters: The first is the typhoon No. 0423 disaster (hereinafter called "T0423"); the second is the typhoon No. 0514 disaster (hereinafter called "T0514"); the third is the heavy rainfall disaster of July 2006 (hereinafter called "HR2006"). These events were the most severe rainfall disasters for 2004, 2005 and 2006, respectively.

2 METHODOLOGY

Basic data come from the outline of disaster statistics provided by the Fire and Disaster Management Agency (FDMA). Detailed information of victims was collected from the national newspapers, local newspapers and web pages of the prefectural offices, municipality offices and elsewhere.

In addition, field surveys and interview surveys were performed in areas that had been seriously damaged. In the case of T0423, Toyooka city in Hyogo prefecture, Maizuru city, Miyazu city and Ooe town in Kyoto prefecture were researched in October 2004. Sumoto city, Tsuna town and Ichinomiya town in Hyogo prefecture and Sanuki city and Higashi-Kagawa city in Kagawa prefecture were researched in November 2004. In the case of T0514, Miyazaki city, Takachiho town and Hinokage town in Miyazaki prefecture were researched in October 2005. In the case of HR2006, Okaya city, Tatsuno town and Suwa city in Nagano prefecture were researched in July 2006. Hishikari town, Ookuchi city and Satsuma town in Kagoshima prefecture were researched in August 2006.

3 OUTLINE OF EVENTS

3.1 T0423

A heavy rainfall caused by typhoon No. 0423 (Tokage, GLIDE: TC-2004-000109-JPN) and a stationary front occurred in western Japan from October 20 to 21, 2004. The highest 1-hour amount of precipitation in the last 25 years was recorded at one observatory, and the highest 24-hour amounts of precipitation in the last 25 years were recorded at 30 observatories based on the data of the Japan Meteorological Agency (JMA, Fig. 1).

In this heavy rainfall, 96 persons were killed, 1,155 houses were destroyed (ruined and half-ruined) and about 62,528 houses were inundated. People died in 16 prefectures, including 7 in Gifu prefecture, 15 in Kyoto, 26 in Hyogo, 11 in Kagawa and 8 in Kochi. The deaths of 31 persons were due to drowning, and 28 people died in sediment disasters.

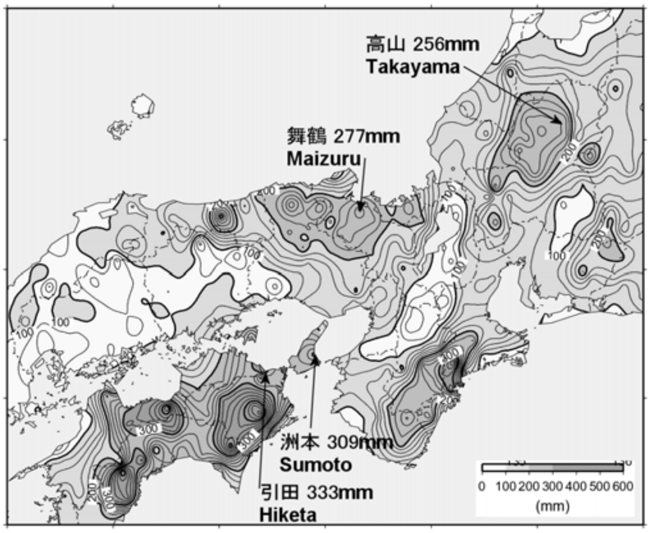

Fig. 1 24-hour precipitation distribution map at 24:00, October 20, 2004

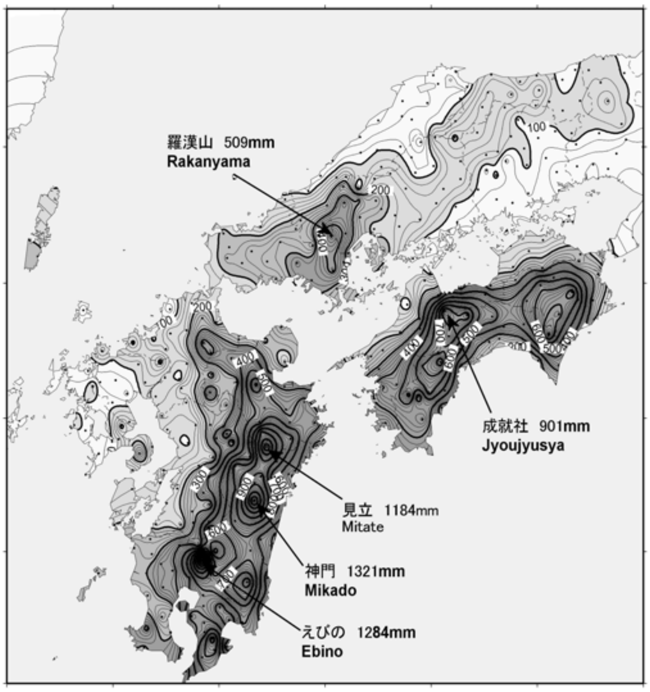

Fig. 2 72-hour precipitation distribution map at 24:00, September 6, 2005

3.2 T0514

A heavy rainfall caused by typhoon No. 0514 (Nabi, GLIDE: TC-2005-000154-JPN) and a stationary front occurred in Japan from September 4 to 8, 2005. A 1238-mm, 48-hour precipitation was recorded at Mikado in Miyazaki prefecture (Fig. 2). This was the highest recorded precipitation of all observatories administered by the Japan Meteorological Agency since 1979. Based on data from the JMA, the highest 24-hour precipitation records in the last 25 years were revised at 56 observatories, and the highest 48-hour precipitation records were revised at 64 observatories as a result of this rainfall. However, there was no observatory where the highest 1-hour precipitation was revised. In this heavy rainfall, 2,834 houses were destroyed and 21,834 houses were inundated; most of the property destruction was caused by inundation. In total, 29 persons were killed or listed as missing in 8 prefectures: 13 in Miyazaki prefecture, 5 in Kagoshima, 4 in Ohita, 3 in Yamaguchi and 4 in others. Of these deaths, 22 were attributable to sediment disasters.

3.3 HR2006

A heavy rainfall caused by a stationary front (Bai-u front) occurred in Japan from July 15 to 24, 2006. A 1107-mm, 72-hour precipitation was recorded at Shibisan in Kagoshima prefecture (Fig. 3). Based on data from the JMA, the highest 1-hour precipitation records since 1979 were revised at 5 observatories, the highest 24-hour precipitation records were revised at 22 observatories and the highest 48-hour precipitation records were revised at 62 observatories as a result of this rainfall.

Due to this heavy rainfall, 342 houses were destroyed and 10,968 houses were inundated (GLIDE: FL-2006-000102-JPN, MS-2006-000102-JPN). In total, 28 persons were killed or listed as missing in 9 prefectures: 12 in Nagano prefecture, 5 in Kagoshima, 4 in Shimane and 7 in others.

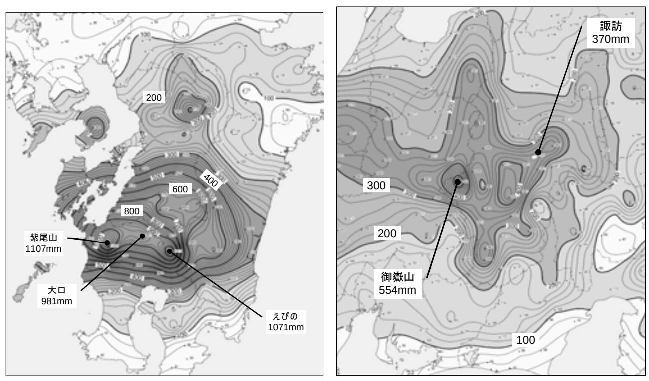

Fig. 3 72-hour precipitation distribution map of HR2006

4 ANALYZATION OF HUMAN DAMAGE

4.1 Identification of the location of the dead

Rough addresses of the places where the dead were found were identified based on the data posted on the web and in newspapers. This address data was converted into latitude and longitude data by use of the "Free Address Geocoding Service for CSV Formatted Files on WWW" (Center for Spatial Information Science, University of Tokyo, 2001). In addition, some locations were modified based on field survey and interview survey results.

Fig. 4 shows the distribution of deaths caused by T0423 based on the latitude and longitude data. The total number of deaths was 96 persons, as stated previously, and the dead were found in 78 places in 60 municipalities. The largest number of deaths was in the area of Uno, in Tamano city, Okayama prefecture, where 5 persons were killed by a sediment disaster. At Murotosaki-cho, Muroto city, Kochi prefecture, 3 persons were killed by high waves. In each of the other localities, one or two persons were killed. Thus, this disaster cannot rightly be called a "local type heavy rainfall disaster" but rather a "wide area type heavy rainfall disaster". Some events known as serious heavy rainfall disasters, such as the Sainin heavy rainfall in 1983 (117 dead) and the Nagasaki heavy rainfall in 1982 (299 dead) were considered local type heavy rainfall disasters. It is likely that a serious wide area type heavy rainfall disaster has not occurred since the heavy rainfall disaster caused by typhoon No. 17 in 1976 (169 dead).

Fig. 5 shows the distribution of deaths caused by HR2006. The total number of deaths was 29 persons. The largest number of deaths was in the area of Minato, in Okaya city, Nagano prefecture, where 7 persons were killed by a sediment disaster. At Sata-cho, Izumo city, Shimane prefecture, 3 persons were killed by flooding. In each of the other localities, one person was killed.

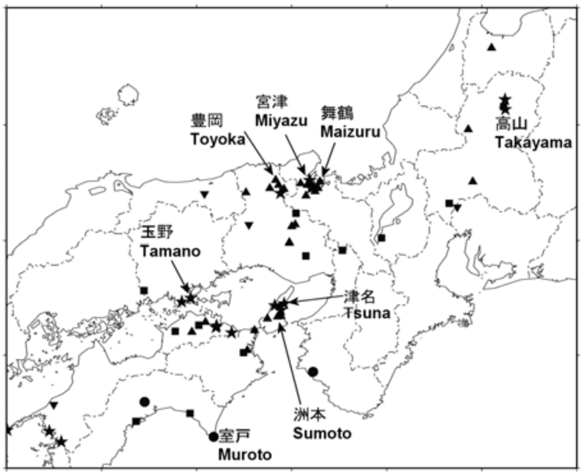

Fig. 4 Distribution map of deaths (T0423)
▲: Floods, ★: Sediment disaster, ●: High waves,
▼: Strong winds, ■: Active accident

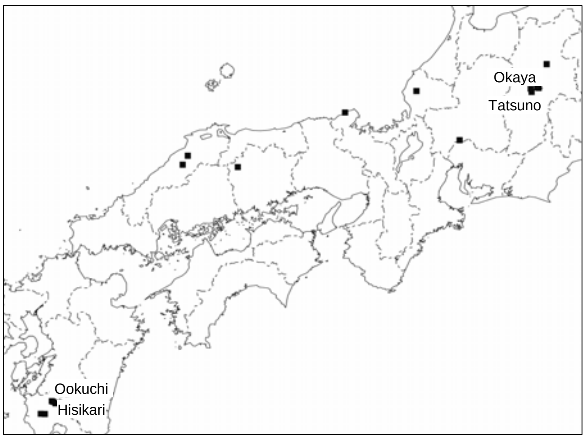

Fig. 5 Distribution map of deaths (HR2006)

4.2 Classification of causes of death

A method for classifying the deaths caused by heavy rainfall disasters has not been established in Japan. In the *Japan Statistical Yearbook*, printed by the Ministry of Internal Affairs and Communications, the causes of deaths by natural disaster are classified into "typhoon", "storm", "strong winds", "high tide", "earthquakes", "volcanoes" and "tsunamis". However, there are several problems with this classification system. One is that it is not clear what the difference is between a "typhoon" and a "storm". Classification by hazards, such as a flood or sediment disaster, is needed. In addition, among the deaths that occurred in the most recent heavy rainfall disaster in Japan, some people were killed due to careless behavior. A classification that takes this into account is also needed. Therefore, in this study, we developed the following classifications:

1) "High waves": death by sea waves along the coast, e.g., death that occurred when the person was inside a house destroyed by high waves, or death caused by being struck by a wave during work or when visiting an area.
2) "Strong winds": death related to strong winds, e.g., death that occurred when a person died because of being blown off a roof by strong winds, or being crushed by a tree felled by strong winds.
3) "Active accident": death by persons who approached a dangerous area instead of evacuating it, or by persons who died after falling into an irrigation canal while patrolling a paddy field or irrigation canal.
4) "Flood": death by flood flow or inundation, e.g., death that occurred by a person drowning in their house, or being carried away by floods while driving a car or walking.
5) "Sediment disaster": death by debris flow, slope failure and landslide.

"Active accident" is the classification that is original to this study. This classification was defined in order to distinguish it from "floods" and "sediment disaster". Passive victims may be considered to be those persons who, for example, stayed indoors, not realizing that their houses would be flooded and that they would drown. Moreover, many of the people who drowned while driving their car or walking were attempting to escape the danger, and they can also be considered "passive" victims. On the other hand, generally persons who died after falling into an irrigation canal while patrolling a paddy field or other area can be classified as "flood victims". As we have seen, there are many such victims recently. They must have known that a swollen irrigation canal could be dangerous, but they still went to the dangerous area and died. They are thus, so to speak, "active victims." Of course, there are various reasons for their behavior, but the behavior of "passive victims" and "active victims" can be considered to differ. Therefore, methods for preventing disaster deaths must also differ. For these reasons, we developed the classification "active accident".

Fig. 6 shows the classification of causes of death from T0423, T0514 and HR2006. In the case of T0423, thirty-two persons died by "flood", and 20 died by "active accident". Deaths by "active accident" were included in the deaths caused by flood in ordinal disaster statistics. Thus, in ordinal disaster statistics, the death toll by flood would be considered 52. The numbers of deaths by flood were far fewer in the latest disaster in Japan. However, in T0423, the number of deaths by flood was higher than that by sediment disaster. In Hyogo prefecture, which suffered the worst damage, 15 of 26 deaths were by flood. Even in Kyoto prefecture, 10 of 15 deaths were caused by flood.

Table 1 Heavy rainfalls causing the deaths of 50 or more persons since the 1980s

Date	Cause of heavy rainfall	Death (persons)	Breakdown (persons)
1982. 7.10 - 26	Nagasaki heavy rainfall	299	Sediment disaster: 263
1982. 8. 1 - 3	Typhoon No. 10 and front	95	Sediment disaster: 56, flood: 15, unknown: 24
1983. 7.20 -27	Sanin heavy rainfall	107	Sediment disaster: 91, flood: 11
1991. 9.24 - 10.1	Typhoon No. 19	62	Most deaths caused by strong wind.
1993. 7.31 - 8.7	Kagoshima heavy rainfall	49	Most deaths caused by sediment disasters.
2005. 7.13	Niigata and Fukushima heavy rainfall	16	Flood: 12, active accident: 2, sediment disaster: 2

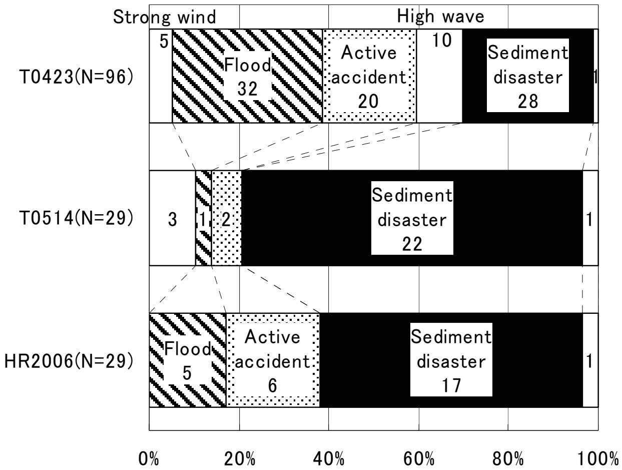

Fig. 6 The number of deaths by cause
Numbers in the bars show the deaths from each cause. "N" is the total number of dead.

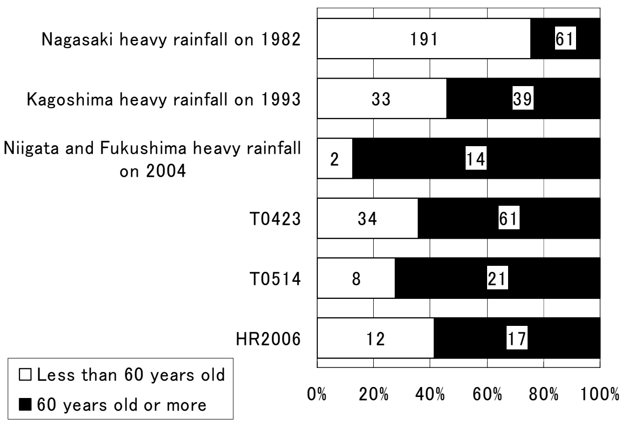

Fig. 7 The death toll of elderly and non-elderly people in the recent serious heavy rainfall disasters.
Numbers in the bars show the deaths from each cause.

Table 1 lists the events since the 1980s in which the number of deaths was 50 persons or more based on three reports (Yoshikawa, 2003; Hiroi and Nakamura, 1992; Takamine, 1994). As the table shows, since the 1980s, most of the deaths were caused by sediment disasters. The death toll by flood in the Nagasaki heavy rainfall disaster of 1982 (about 30 persons) was the most serious of these events. The death toll by T0423 is the largest since 1982. Many persons were killed by flood in the Niigata and Fukushima heavy rainfall disasters, but the death toll by flood in T0423 exceeded those numbers. Serious harm to humans caused by floods has not occurred for about the past 20 years. However, this was evidently a matter of luck, as the harm caused by T0423 shows that there is always a possibility that serious damage will occur.

In the case of T0514 and HR2006, the majority of victims were killed by sediment disasters. These events show similar characteristics to those of the other heavy rainfall disasters shown in Table 1.

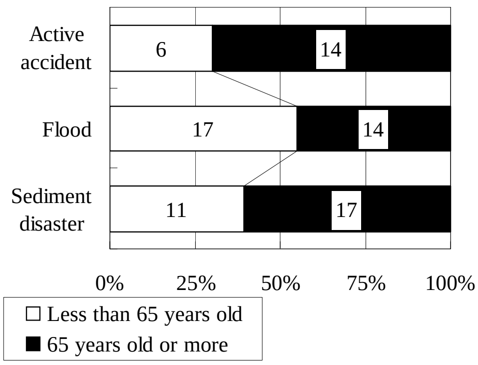

Fig. 8 The death toll by age and cause of death (T0423).

4.3 Relationship between cause of death and age

To examine the relationship between cause of death and age, I first totaled the victims according to age. In the case of T0423, 41 victims were under age 65 and 54 over age 65, the typical age labeled the “elderly.” When the threshold for the elderly label was set at 60 years old, there were 34 persons under age 60 and 61 persons over age 60. Thus, elderly people accounted for about 60 percent of the total victims. Fig. 7 shows the death toll of the elderly in recent serious heavy rainfall disaster events. In this figure only, "elderly people" are defined as persons over 60 years old by data constraint. This figure shows that the majority of victims were elderly people in recent heavy rainfall disaster events. We can say with a fair amount of certainty that the "victims by heavy rainfall disaster were unevenly distributed among elderly people". However, it is necessary to examine this issue from another point of view as well.

Fig. 8 shows the relationship between cause of death and age in T0423. The death rates of elderly people (over 65 years old) were slightly more than half the totals in the active accident and sediment disaster classifications. However, the death rate by flood among non-elderly people (under 65 years old) is less than half the totals. Almost all of these victims were washed away by floods while driving or walking.

4.4 Possibility of human damage mitigation by using disaster prevention information

I attempted to estimate how much human damage can be mitigated when disaster prevention information, such as rainfall forecasts, real-time precipitation data, hazard maps and other tools, is used. The objects of estimation are the victims of flood, sediment disaster and active accident.

First, the victims by flood were classified based on the location where they were killed. The locations were classified as follows:

(1) In their home
(2) Outdoors near their home
(3) Outdoors far from their residence area.

It is possible that the victims who died in locations (1) and (2) could have been saved if the following necessary conditions had been satisfied:

(a) By viewing a hazard map, they understood that it was dangerous near their house.
(b) The real-time precipitation or river water level information was gathered and disseminated through the Internet, radio and other means.
(c) The present precipitation or water level was understood to have reached dangerous levels for the region.

The information contained in (b) is disseminated now in Japan, and hazard maps of floods have been released in national administrated rivers to the public via printed matter or web pages. Of course, it is not easy for the three conditions listed above to be satisfied, but it is not impossible.

On the other hand, it could be very difficult to save (3) type victims. They are killed at far from their residence area. Most of these victims are making trips by car or walking for commuting purposes or on business. Therefore, it is likely that hazard information would not be useful to them, even if they could see the hazard map for their residence area. It is not impossible to pass information gathered about real-time rainfall and river water levels by mobile phone and other methods, but it is not easy for non-experts to use this information, because most people don't know how gather information on real-time rainfall and river water levels or how to use this information to help them remain safe. In addition, the present information on flood forecasts does not show the inundation depths inland (away from rivers).

In the case of T0423, 32 persons were killed by flooding. Judging from the above criteria, the number of victims who could have been saved by additional information was estimated at 8 persons. This was the sum of victims in location type (1) (6 persons) and victims in location type (2) (2 persons). All were elderly, over 65 years old. It would have been difficult to save the victims in location type (3), 24 persons, using this information. Seventeen of them were not elderly people. That is, people become vulnerable to disasters regardless of age when they are taking a trip. It is necessary to develop an information transmission method or system for people who are traveling, not only using IT but

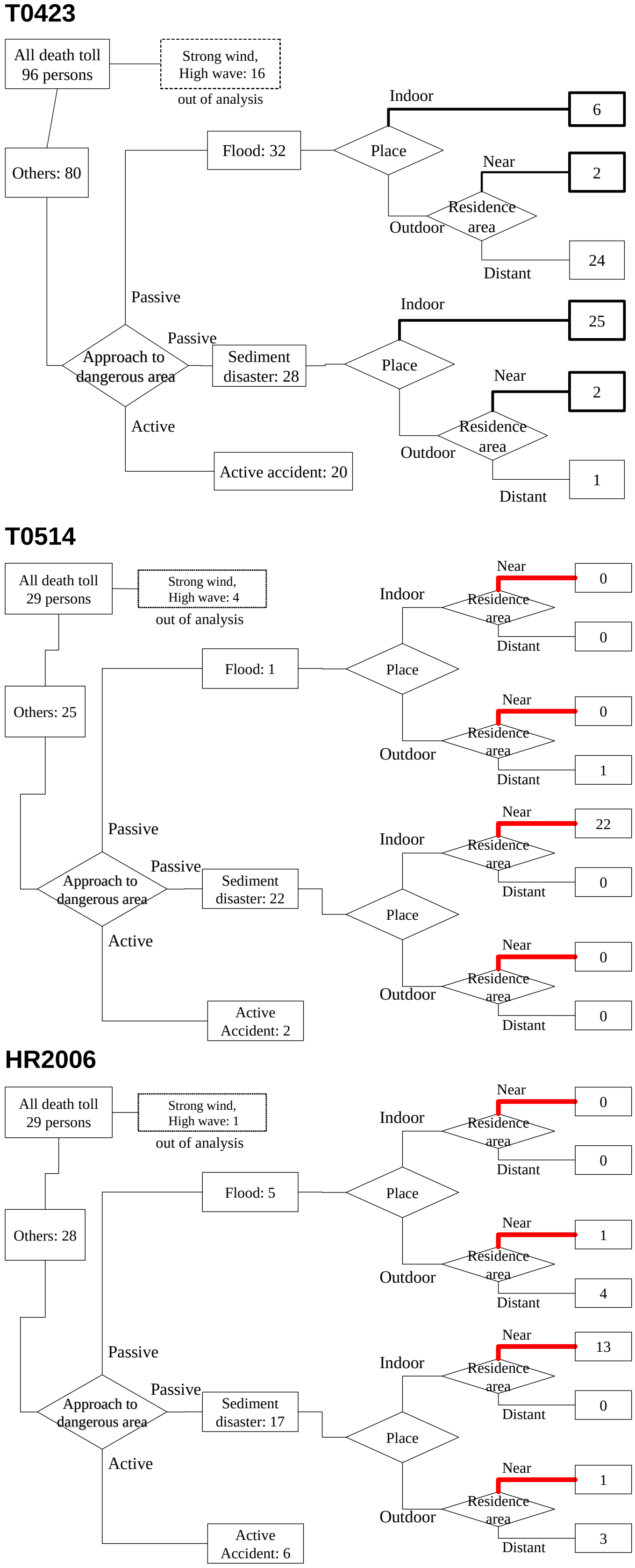

Fig. 9 Flow chart analysis of causes of death in a disaster

all available technology.

In the case of T0423, most of the 25 persons killed by sediment disasters were killed inside their homes. Although three persons were killed outdoors, two of them were killed beside their homes. That is, 27 victims were in location type (1) or (2). Therefore, it is possible that the victims could have been saved if the necessary conditions (a), (b) and (c) listed above had been satisfied. Judging from the above, in the case of victims by sediment disaster, 27 persons could have been saved by obtaining information.

As we have seen, the victims who died by an "active accident" were defined as "persons who died because they approached the dangerous area by themselves instead of evacuating". Since these people approached the dangerous area of their own free will, it is probable that their decision would not have been changed only by receiving disaster information. Therefore, it is unlikely that these victims could have been saved, even if all necessary conditions had been in place.

Refuge guidance at the time of a disaster is often considered support for elderly people. However, in the case of T0423, 14 of the 20 victims who died from an "active accident" were elderly people. It is possible that this number could not have been reduced, even if an evacuation guiding system for elderly people had been in place. Nonetheless, it is important to provide the elderly with information and support so that they do not become victims of an "active accident".

Fig. 9 is a diagram of the results of the above estimation. The thick line is a connector related to disaster prevention information. In the case of T0423, the number classified into the lower side of the connectors is 35 persons. It is possible that if the proposed disaster prevention information had been used, 35 persons (39% of all) maximum would have been saved. In the case of T0514 and HR2006, 22 persons (76%) and 15 persons (52%) might have been saved, respectively.

5 CONCLUSIONS

In the case of T0423, 96 persons were killed, the highest death toll by heavy rainfall in Japan since the “Heavy rainfall in July 1983” (117 persons dead). Several heavy rainfall disasters occurred in 2004 in Japan, including the "Niigata and Fukushima heavy rainfall in 2004", in which 16 persons died, the the "Fukui heavy rainfall disaster in 2004" (5 persons), Typhoon No. 0416 (17 persons), Typhoon No. 0418 (45 persons) and Typhoon No. 0421 (27 persons). These disasters had a strong impact on the Japanese government, and several committees for heavy rainfall disaster prevention policy were formed. The Ministry of Land, Infrastructure and Transport (MLIT, 2005) made the following points about the recent heavy rainfall disasters:

(1) The damage was unevenly distributed among "people vulnerable to disasters", such as the elderly and handicapped persons.

(2) Mutual help of resident communities at the time of disaster became inactive.

(3) The awareness among residents of the dangers of natural disasters is decreasing.

(4) The danger of underground spaces flooding is increasing.

The above points need to be discussed further. As we have seen, one of the most important points to note about the disaster studied here is that 32 of the 96 victims were killed outdoors by floods. This was a very rare circumstance when other recent heavy rainfall disaster events are considered. The victims were not only elderly people, and it would have been difficult to save them by mutual help, point (2), or improvement in the awareness about disasters, point (3).

It must be noted that there is a limit to the effect of disaster information. Based on the analysis of this study, it is estimated that if the available disaster prevention information had been used, 22 persons (76% of all victims) maximum would have been saved in the case of HR2006. However, in the case of T0423, the estimation is only 39% (36 persons). Further research and analysis into the causes of death by heavy rainfall disaster would clarify the issues that need to be addressed.

NOTE

This paper is a revision of an earlier study by Ushiyama (2006).

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